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Foraging Preferences of Canada Geese Among Turfgrasses: Implications for Reducing Human–Goose Conflicts

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ABSTRACT Canada geese (*Branta canadensis*) can cause serious damage to turfgrass areas and create human health and safety concerns (e.g., collisions with aircraft, disease transmission). We conducted a study during 2005–2007 to determine if Canada geese exhibit a feeding preference among various commercially available turfgrasses. Behavioral responses of captive geese to 9 turfgrasses, bare ground, and litter were observed over 6 4-week trials during July–September following the installation of selected turfgrasses into experimental arenas. Captive geese preferred to forage on Kentucky bluegrass, creeping bentgrass, and fine fescue sods compared to centipedegrass, St. Augustinegrass, and zoysiagrass. Forage qualities and macronutrient levels varied among the turfgrasses and might explain the foraging preferences geese exhibited during this study. Canada goose feeding rate was positively correlated with crude protein, nitrogen content, and calcium, but negatively correlated with acid detergent fiber content, within various turfgrasses. Our findings suggest careful selection of turfgrasses could be an effective method for reducing Canada goose conflicts in urban and suburban areas. © 2011 The Wildlife Society.

KEY WORDS *Branta*, feeding, geese, landscape management, nutrition, turfgrasses, urban.

Human–wildlife conflicts occur throughout the world and involve a wide variety of wildlife species and a diversity of problems, including damage to agricultural crop and forest resources, impacts to livestock production, issues related to invasive and exotic species, and wildlife–human disease transmission (Bruggers et al. 2002, Conover 2002, Messmer 2009). Conflicts between humans and wildlife frequently occur in suburban and urban areas, where high densities of humans and wildlife species adapted to living in close proximity to humans co-exist (Adams et al. 2005).

Resident (i.e., non-migratory) Canada geese (*Branta canadensis*) can be a significant problem within urban and suburban environments. In addition to causing direct damage to vegetation (via trampling and removal), geese grazing on turfgrasses and plants in manicured industrial lawns, parks and recreational areas, on sports fields, on golf courses, and around private homes can adversely affect humans and their use of such areas by littering these areas with feces (Conover and Chasko 1985, Conover 1991). Urban geese directly affect human health and safety by posing a risk to safe aircraft operations (Dolbeer et al. 2000, Dolbeer 2009), contaminating water resources (Conover and Chasko 1985, Manny et al. 1994), behaving aggressively during the nesting season (Smith et al. 1999), and potentially transmitting diseases to humans (Feare et al. 1999, Kullas et al. 2002, Olsen et al. 2006).

Integrated wildlife damage management programs that use a variety of tools and techniques are most effective for reducing human–wildlife conflicts (Fall and Jackson 2002). Management efforts to address resident Canada goose conflicts often involve the use of hazing and scare devices (Smith et al. 1999, York et al. 2000, Holevinksi et al. 2007), habitat modification (Cooper 1998), translocation of individuals (Cooper and Keefe 1997), or lethal removal of geese (Cooper and Keefe 1997, Smith et al. 1999). One component of a management program to reduce human–goose conflicts could be to reduce the attractiveness of turfgrass areas to Canada geese by installing plant species and cultivars (cv.) that are not favored by foraging geese. However, this aspect must be balanced with the aesthetic and recreational values of turfgrass areas for humans (Ulrich 1986, Casler 2006) and the availability, ease of establishment, and maintenance ability of selected turfgrass species and cultivars (Casler and Duncan 2003, Casler 2006).

Knowledge of Canada goose foraging behavior and feeding preferences, especially related to commercially available turfgrasses that are commonly used in urban and suburban situations, could be useful in alleviating human–goose conflicts (Cooper 1998, Conover 1991, Washburn et al. 2007). The objectives of our study were to: 1) determine if Canada geese exhibit a foraging preference when given a choice among various commercially available turfgrass types used

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in the United States, 2) quantify forage qualities and nutritional content of these turfgrasses, and 3) identify turfgrass characteristics that might influence foraging preferences by Canada geese.

STUDY AREA

We conducted this study from June through October 2005–2007 at the National Aeronautics and Space Administration's Plum Brook Station, Erie County, Ohio (41°37′ N, 82°66′ W). Existing goose housing facilities (associated with a fenced 2-ha pond) adjacent to grasslands allowed for experiments on behavioral response of captive birds to different vegetation types without the disturbances characteristic of urban feeding sites (e.g., golf courses).

METHODS

Study Animals

We captured wild adult Canada geese of undetermined sex in northern Ohio during the molt period (i.e., June) of 2005–2007 and transported them to our goose holding facilities where they were provided whole-kernel corn, poultry pellets, grass, and water ad libitum. We trimmed the primary feathers from the right wing of each bird prior to releasing them into the holding facility so that the birds would remain flightless during experiments.

Prior to each experiment, we randomly selected 24 experimentally naive geese and herded them into a 0.4-ha holding pen that was adjacent to the main holding facility. Whole-kernel corn, poultry pellets, shade, grass, and a 20-m^2 area of the pond were available to geese in the holding pen. Each goose was randomly assigned to 1 of 6 arenas (i.e., 4 geese per arena). We placed an arena-specific color-coded neck band on each goose to ensure the same geese were placed into the same arena throughout an experiment.

Experimental Design

Each year of the study, we established 5 experimental and 1 control arenas (12.2 m $\times$ 15.2 m). Each arena was divided into 4 6.1-m $\times$ 7.6-m plots. We assigned 1 of 4 turfgrasses to each plot within an arena prior to arena construction. We obtained and installed turfgrass sods into the appropriate plot within each arena during June of each year. During 2005 (experiments 1 and 2), the 4 turfgrasses studied included Kentucky bluegrass (*Poa pratensis* L.; equal mixture of Nudestiny, Award, Rugby II, and Absolute cv.), tall fescue (*Schedonorus phoenix* (Scop.) Holub) [an equal mixture of an endophyte-free cv. (Arid III) and a high-endophyte cv. (Pixie)], common bermudagrass (*Cynodon dactylon* L.) cv. Quickstand, and zoysiagrass (*Zoysia japonica* Steudel) cv. Zenith. During 2006 (experiments 3 and 4), only 3 turfgrass sods [creeping bentgrass (*Agrostis stolonifera* L.) cv. Penncross, buffalograss (*Buchloe dactyloides* (Nutt.) Engelm) cv. Legacy, and zoysiagrass cv. Zenith] could be delivered in time for establishment. The fourth plot within each of the 6 arenas was treated as bare ground (i.e., no sod and vegetation killed with glyphosate [Round-up PRO^{TM}, Monstanto Inc., St. Louis, MO]). Following the end of experiment 3, we killed all 5 creeping bentgrass plots using glyphosate on 21 August 2006 because of significant mortality and declines in the quality of the bentgrass turf. Thus, litter (i.e., dead grass) replaced creeping bentgrass as a treatment during experiment 4. During 2007 (experiments 5 and 6), the 4 turfgrasses included fine fescue (mixture comprised of 40% hard fescue [*Festuca trachyphylla* (Hackel) Krajina] cv. Nordic, 40% creeping red fescue [*F. rubra* ssp. *rubra* Gaudin] Audubon, and 20% chewings fescue [F. rubra ssp. *commutate* (Thuill.) Nyman] cv. Jamestown IV), centipedegrass (*Eremochloa ophiuroides* (Munro) Hack.) cv. Common, St. Augustinegrass (*Stenotaphrum secundatum* (Walt.) Kuntze) cv. Palmetto, and zoysiagrass cv. Zenith. Kentucky bluegrass sod was placed in all 4 plots within the control arena in 2005 (experiments 1 and 2), zoysiagrass sod was placed in 3 of the 4 plots within the control arena in 2006 (experiments 3 and 4), and zoysiagrass sod was placed in all 4 plots within the control arena in 2007 (experiments 5 and 6).

Following installation and establishment of the turfgrass sod, we erected a 1.5-m tall black plastic fence around the 6 arenas to keep the geese within their respective arenas. We mowed all plots within the arenas to a height of 15–20 cm prior to the start of the first experiment each year so that all turfgrasses were initially of similar height.

Goose Behavioral Observations

Each day of an experiment, we placed 2 0.5-m diameter pans of water centrally within each arena. We herded 4 geese into each arena daily by 0830 hours and allowed them to graze on the turfgrasses until 1200 hours, when we returned them to their holding pen. Three observers stationed on 4.9-m tall towers 20 m from the arenas monitored goose activity. We observed geese for 2 1-hour periods (0.5 and 2.5 hr after we herded geese into arenas) 3 days per week for 4 weeks. Each observer watched 2 arenas, alternating between arenas every minute. At the start of each minute, observers recorded the initial number of geese in each turfgrass plot, then for the following 0.5 minute counted the number of bill contacts (total for all 4 geese) with each turfgrass plot in the arena (Washburn et al. 2007). We conducted behavioral observations of the geese for 12 days during 27 July–19 August 2005 (experiment 1), 24 July–18 August 2006 (experiment 3), and 6 July–1 August 2007 (experiment 5).

Following the end of the first experiment each year, the turfgrasses were not grazed by geese for at least 10 days. We mowed all turfgrass plots to a height of 15–20 cm prior to the start of the second experiment. We selected a new set of 24 experimentally naive geese, placed them into the holding pen, and fitted them with color-coded neck bands. We conducted behavioral observations of geese during the second 4-week experiment each year for 12 days during 29 August–22 September 2005 (experiment 2), 11 September–6 October 2006 (experiment 4), and 10 August–5 September 2007 (experiment 6).

Turfgrass Forage Quality

We collected fresh samples of the 9 turfgrasses between experiments. We collected 6 replicate samples of each turfgrass from randomly selected arenas by cutting the grass swards with electric clippers. We removed dead plant material by hand to ensure samples contained only living plant material. We immediately placed 3 samples of each turfgrass into plastic bags and froze the samples at -20° C within 15 minutes of collection. We placed the remaining 3 samples of each turfgrass in a drying oven within 30 minutes of collection and dried them for 48 hours at 50° C. We stored dried turfgrass samples individually in paper bags.

We transported frozen turfgrass samples to the Holmes Laboratory, Inc. (Millersburg, OH) for forage and feed analyses. They used standard laboratory methods (Association of Official Analytical Chemists 2007) to determine forage qualities (moisture content, crude fat, crude protein, water-soluble carbohydrates [WSC], acid detergent fiber [ADF], neutral detergent fiber [NDF], lignin, and ash) from each of the 9 turfgrasses. Acid detergent fiber (i.e., cellulose + lignin) has been shown to be a reliable estimator of digestibility of foods in Anatidae (Prop and Deerenberg 1991, Durant et al. 2003). Neutral detergent fiber (i.e., ADF + hemicelluose) is inversely related to forage intake, thus as NDF increases total intake decreases (Pond et al. 1995).

We sent dried turfgrass samples to the Pennsylvania State University Agricultural Analytical Services Laboratory (University Park, PA) for nutrient and silica content analyses. They used standard laboratory methods for plant tissue analysis (Miller 1998) to determine macronutrient levels (nitrogen, phosphorus, potassium, calcium, magnesium, and sodium) and total silicon in each of the 9 turfgrasses. In grasses, silica uptake is a plant defense against herbivory (Vicari and Bazely 1993) and thus might influence foraging rates by geese.

Statistical Analyses

We analyzed Canada goose behavioral and feeding rate data from each of the 6 foraging experiments independently. Goose behavioral and foraging data collected during successive observations are likely not independent. Therefore, we computed a daily average of the number of geese per plot and bill contacts per minute for all 4 geese combined (hereafter BCPM) for each turfgrass type (i.e., plot) within each arena. We compared the average number of geese observed and the BCPM in each turfgrass type using repeated measures analysis of variance with turfgrass type as a fixed effect, the 5 arenas as replications, and the 12 days as repeated measures (Crowder and Hand 1990). When the main effect (turfgrass type) was found to be significant, we conducted means comparisons using Fisher's protected Least Significant Difference (LSD) tests (Zar 1996). We considered differences significant at $P \leq 0.05$ and conducted all statistical analyses using SAS 9.1 (SAS Institute, Inc., Cary, NC). Additionally, we used linear regression analysis (Zar 1996) to determine if trends in goose foraging rate occurred within individual turfgrass types during each experiment.

We compared forage quality characteristics (moisture, crude fat, crude protein, WSC, ADF, NDF, lignin, and ash), macronutrient levels (nitrogen, phosphorus, potassium, calcium, magnesium, and sodium), and total silica content among the 9 turfgrasses using Kruskal–Wallis tests and considered differences significant at $P \leq 0.05$ (Zar 1996).

We identified potential relationships between observed goose foraging and the forage quality and nutritional characteristics of the turfgrasses. We calculated Pearson's correlation coefficient for goose foraging rate (BCPM; averaged across experiments) with each forage quality characteristic (moisture, crude fat, crude protein, WSC, ADF, NDF, lignin, and ash), macronutrient level (nitrogen, phosphorus, potassium, calcium, magnesium, and sodium), and total silica content for each of the 9 turfgrasses and considered correlations to be significant at $P \leq 0.05$ (Zar 1996).

RESULTS

Goose Behavioral and Foraging Observations

During experiment 1, the numbers of geese observed did not differ ($F_{3,16} = 1.86$, $P = 0.18$) and the BCPM was not statistically different ($F_{3,16} = 2.87$, $P = 0.07$) among the 4 turfgrasses (Table 1). However, the BCPM by geese in bluegrass, tall fescue, and bermudagrass plots was more than 22 times greater than BCPM by geese in zoysiagrass plots (Fig. 1A). We believe this difference is biologically significant and represents an important difference in feeding rate. Canada geese foraged in the Kentucky bluegrass control

Table 1. Mean number of Canada geese per plot and mean number of bill contacts per minute (for 4 geese combined) during 6 experiments with commercially available turfgrasses. Data are presented as mean ± 1 SE.

Turfgrass	No. of geese per plot[a]	Bill contacts per minute[a]
Experiment 1		
Kentucky bluegrass	0.8 ± 0.1 A	22.3 ± 6.6 A
Tall fescue	1.2 ± 0.5 A	22.4 ± 10.2 A
Common bermudagrass	1.2 ± 0.3 A	28.4 ± 7.5 A
Zoysiagrass	0.4 ± 0.1 A	0.8 ± 0.2 A
Experiment 2		
Kentucky bluegrass	1.7 ± 0.2 A	81.7 ± 11.2 A
Tall fescue	0.6 ± 0.2 B	5.3 ± 1.4 C
Common bermudagrass	1.0 ± 0.2 AB	19.3 ± 3.4 B
Zoysiagrass	0.4 ± 0.2 B	1.9 ± 0.6 C
Experiment 3		
Creeping bentgrass	1.2 ± 0.2 A	41.9 ± 5.0 A
Buffalograss	0.7 ± 0.2 A	18.8 ± 5.4 AB
Zoysiagrass	0.6 ± 0.2 A	6.0 ± 2.3 B
Bare ground (no grass)	1.1 ± 0.3 A	1.3 ± 0.4 B
Experiment 4		
Litter (dead grass)	0.7 ± 0.3 A	0.5 ± 0.2 A
Buffalograss	1.8 ± 0.3 B	36.5 ± 3.6 B
Zoysiagrass	0.6 ± 0.3 A	6.2 ± 2.5 A
Bare ground (no grass)	0.7 ± 0.1 A	1.1 ± 0.3 A
Experiment 5		
Fine fescue	2.0 ± 0.4 A	19.0 ± 3.4 A
Centipedegrass	0.8 ± 0.2 B	4.1 ± 1.0 B
St. Augustinegrass	0.5 ± 0.2 B	5.6 ± 1.6 B
Zoysiagrass	0.4 ± 0.1 B	3.6 ± 0.9 B
Experiment 6		
Fine fescue	1.8 ± 0.2 A	32.0 ± 5.3 A
Centipedegrass	0.7 ± 0.3 B	6.3 ± 2.4 B
St. Augustinegrass	0.5 ± 0.2 B	2.7 ± 0.9 B
Zoysiagrass	0.4 ± 0.1 B	3.0 ± 1.1 B

[a] Within each experiment, means within the same column with the same letter are not different ($P > 0.05$).

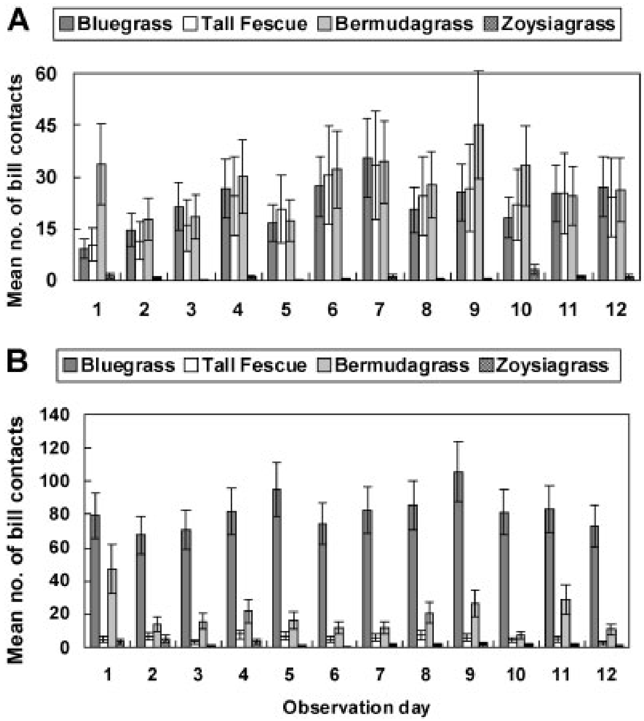

Figure 1. Mean number of bill contacts per minute by captive Canada geese in 5 arenas of 4 turfgrass plots during (A) experiment 1, 27 July–19 August 2005 and (B) experiment 2, 29 August–22 September 2005.

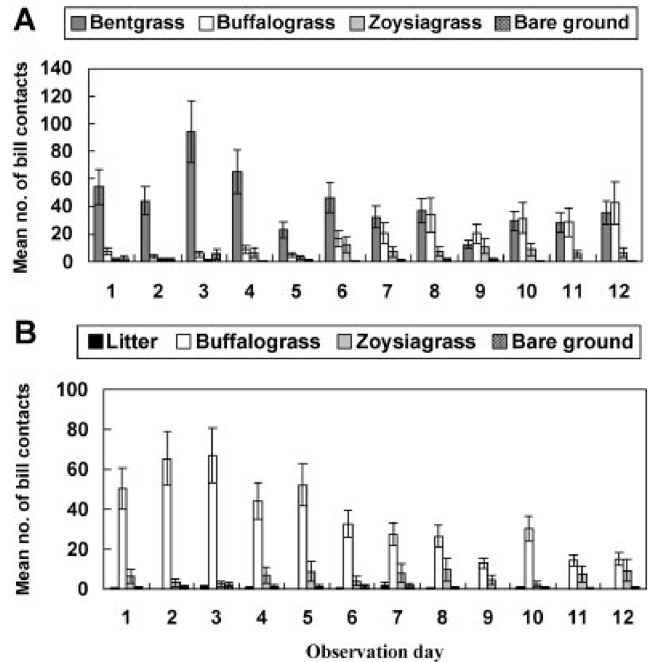

Figure 2. Mean number of bill contacts per minute by captive Canada geese in 5 arenas of 4 turfgrass plots during (A) experiment 3, 24 July–18 August 2006 and (B) experiment 4, 11 September–6 October 2006.

arena plots (10.6 BCPM) at rates consistent with foraging in bluegrass sod within the other 5 arenas. Overall, captive Canada geese spent similar amounts of time in all 4 types of turfgrass but foraged almost exclusively on the Kentucky bluegrass, tall fescue, and common bermudagrass sod (Fig. 1A).

During experiment 2, the numbers of geese observed in Kentucky bluegrass were greater ($F_{3,16} = 10.61$, $P \leq 0.001$) than in tall fescue and zoysiagrass plots, whereas the numbers of geese in common bermudagrass plots were similar to the other 3 turfgrasses (Table 1). The BCPM by geese in bluegrass was 4–43 times greater ($F_{3,16} = 39.79$, $P \leq 0.001$) than in tall fescue, bermudagrass, and zoysiagrass plots (Table 1). Canada geese foraged in the Kentucky bluegrass control arena plots (18.0 BCPM) at a rate less than in the other 5 arenas. Overall, captive Canada geese preferred to loaf, preen, rest, and forage in Kentucky bluegrass plots compared to tall fescue and zoysiagrass plots (Fig. 1B).

During experiment 3, the numbers of geese observed was similar ($F_{3,16} = 2.38$, $P = 0.11$) among the 3 turfgrass and bare ground plots (Table 1). The number of bill contacts by geese in creeping bentgrass plots was 7–32 times greater ($F_{3,16} = 21.79$, $P < 0.001$) than the number of bill contacts by geese in zoysiagrass or bare ground plots; the number of bill contacts by geese in buffalograss was intermediate (Table 1). Canada goose foraging on creeping bentgrass decreased (linear regression: $y = -3.6211x + 65.402$, $R^2 = 0.36$, $F_{1,11} = 5.67$, $P = 0.04$), while foraging on buffalograss increased (linear regression: $y = 3.3213x - 2.838$, $R^2 = 0.83$, $F_{1,11} = 47.27$, $P < 0.001$) from the beginning to the end of experiment 3 (Fig. 2A). Canada geese in the control arena plots foraged in the zoysiagrass (12.3 BCPM) and bare ground (2.7 BCPM) plots similarly to the other 5 arenas. Overall, geese spent similar amounts of time in all 3 turfgrass and bare ground plots but foraged almost exclusively in the creeping bentgrass and buffalograss plots (Fig. 2A).

During experiment 4, more ($F_{3,16} = 4.46$, $P = 0.02$) geese were observed in buffalograss than in zoysiagrass, bare ground, and litter plots (Table 1). The number of bill contacts by geese in buffalograss was 6–73 times greater ($F_{3,16} = 60.68$, $P < 0.001$) than the number of bill contacts by geese in zoysiagrass, bare ground, and litter plots. Canada goose foraging on buffalograss decreased (linear regression: $y = -3.6211x + 65.402$; $R^2 = 0.79$, $F_{1,11} = 37.08$, $P < 0.001$) from the beginning to the end of experiment 3 (Fig. 2B). Canada geese foraged in the zoysiagrass (10.2 BCPM) and bare ground (1.0 BCPM) control plots at rates consistent with foraging within the other 5 arenas. Overall, captive Canada geese preferred to loaf, preen, rest, and forage in buffalograss plots compared to zoysiagrass, bare ground, and litter plots (Fig. 2B).

During experiments 5 and 6, the numbers of geese observed in fine fescue were greater (experiment 5: $F_{3,16} = 8.29$, $P = 0.002$; experiment 6: $F_{3,16} = 9.59$, $P \leq 0.001$) than in centipedegrass, St. Augustinegrass, and zoysiagrass plots (Table 1). The number of bill contacts by geese in fine fescue was 3–5 times greater ($F_{3,16} = 13.81$, $P \leq 0.001$) and 5–12 times greater ($F_{3,16} = 22.58$, $P \leq 0.001$) than the number of bill contacts by geese in centipedegrass, St. Augustinegrass, and zoysiagrass plots during experiments 5 and 6, respectively. Canada geese in the control plot arena foraged in the

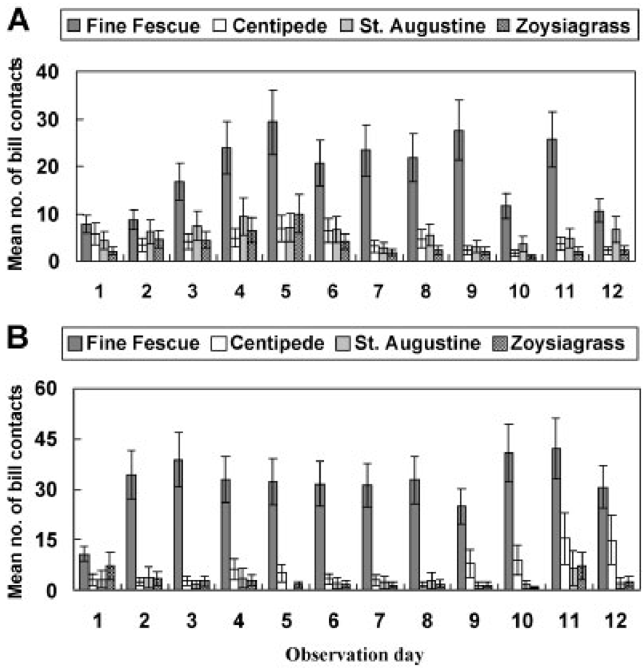

Figure 3. Mean number of bill contacts per minute by captive Canada geese in 5 arenas of 4 turfgrass plots during (A) experiment 5, 6 July–1 August 2007 and (B) experiment 6, 10 August–5 September 2007.

zoysiagrass control plots (experiment 5: 7.3 BCPM; experiment 6: 11.5 BCPM) at rates consistent with foraging in the zoysiagrass plots within the other 5 arenas. Overall, captive Canada geese preferred to loaf, preen, rest, and forage in fine fescue plots compared to centipedegrass, St. Augustinegrass, and zoysiagrass (Fig. 3A,B).

Turfgrass Forage Quality

Forage quality characteristics (Table 2) varied among the 9 turfgrasses (all $H_8 > 18.2$, $P < 0.03$). Buffalograss had the lowest moisture content, whereas creeping bentgrass had the highest (Table 2). Fine fescue and centipedegrass had greater crude fat than tall fescue (Table 2). Kentucky bluegrass and creeping bentgrass had greater levels of crude protein than common bermudagrass and zoysiagrass (Table 2). Acid detergent fiber was lowest in Kentucky bluegrass and creeping bentgrass and highest in buffalograss and zoysiagrass (Table 2). Tall fescue had less NDF and more WSC than zoysiagrass (Table 2).

Macronutrient levels (Table 3) varied among the 9 turfgrasses (all $H_8 > 24.0$, $P < 0.003$). Kentucky bluegrass and creeping bentgrass had greater nitrogen content than common bermudagrass and zoysiagrass (Table 3). Calcium levels were highest in common bermudagrass and lowest in St. Augustinegrass and zoysiagrass (Table 3). St. Augustinegrass had sodium levels that were 5–72 times greater than the other 8 turfgrasses studied (Table 3). Buffalograss had greater total silica content than fine fescue and creeping bentgrass (Table 3).

Relationships Between Turfgrass Forage Quality and Goose Foraging

Goose foraging rate (i.e., BCPM) and forage quality characteristics of turfgrasses were positively correlated for crude protein ($r = 0.70$, $P = 0.03$, $n = 9$ grasses) and negatively correlated for ADF ($r = -0.71$, $P = 0.03$, $n = 9$), whereas correlations between goose foraging rate and turfgrass forage qualities were absent (all $P > 0.05$) for moisture, ash, crude fiber, WSC, NDF, and lignin. Goose foraging rate and macronutrient levels in the turfgrasses were positively correlated for nitrogen ($r = 0.73$, $P = 0.03$, $n = 9$) and calcium ($r = 0.75$, $P = 0.02$, $n = 9$), whereas correlations between goose foraging rate and turfgrass forage qualities were absent (all $P > 0.05$) for the other macronutrients measured (phosphorus, potassium, magnesium, sodium) and total silica content.

DISCUSSION

Our findings clearly demonstrate that Canada geese were making choices and exhibiting preferences when foraging among the turfgrass plots. The forage selection patterns of Canada geese for Kentucky bluegrass in this study are consistent with the findings of other research (Conover 1991, Pochop et al. 1999). Conover (1991) found that Canada geese readily foraged on colonial bentgrass (*Agrostis castellana* Boiss. & Reuter cv. Highland), a cool-season grass very

Table 2. Forage qualities of Kentucky bluegrass (KYB), common bermudagrass (BERM), tall fescue (TTF), zoysiagrass (ZOY), creeping bentgrass (BENT), buffalograss (BUFF), fine fescue (FF), centipedegrass (CENT), and St. Augustinegrass (ST. AUG). Data are presented as mean ± 1 SE.

Turfgrass	Moisture (%)	Ash (%)	Crude fat (%AFDW[a])	Crude protein (%AFDW)	WSC[b] (%AFDW)	ADF[c] (%AFDW)	NDF[d] (%AFDW)	Lignin (%AFDW)
KYB	69.9 ± 1.7	8.5 ± 0.3	2.7 ± 0.1	22.8 ± 0.5	20.0 ± 1.0	24.5 ± 1.2	55.5 ± 1.0	0.5 ± 0.2
BERM	57.0 ± 3.9	6.6 ± 0.1	1.6 ± 0.2	11.4 ± 0.5	8.7 ± 3.7	31.2 ± 0.2	76.1 ± 3.0	3.9 ± 0.3
TTF	72.6 ± 1.5	11.9 ± 0.1	1.4 ± 0.1	15.3 ± 0.8	24.9 ± 0.9	29.4 ± 0.5	52.0 ± 0.7	0.9 ± 0.1
ZOY	62.8 ± 2.1	7.7 ± 0.2	1.6 ± 0.1	11.8 ± 0.7	3.3 ± 1.3	33.3 ± 0.4	80.9 ± 1.3	2.1 ± 0.2
BENT	85.2 ± 1.3	14.6 ± 1.3	2.6 ± 0.1	31.2 ± 0.5	16.3 ± 2.9	23.2 ± 0.4	62.2 ± 9.9	1.2 ± 0.4
BUFF	45.3 ± 0.9	8.6 ± 0.1	1.6 ± 0.1	14.4 ± 0.5	10.7 ± 3.0	32.8 ± 0.4	72.3 ± 3.0	2.7 ± 0.1
FF	72.4 ± 2.1	8.7 ± 0.1	3.2 ± 0.1	20.2 ± 0.3	11.9 ± 5.9	28.6 ± 0.5	67.4 ± 8.1	0.6 ± 0.1
CENT	75.2 ± 1.0	8.9 ± 0.2	3.4 ± 0.4	13.7 ± 0.8	12.7 ± 3.6	31.0 ± 1.2	68.8 ± 3.1	1.3 ± 0.3
ST. AUG	76.6 ± 1.5	9.7 ± 0.2	2.0 ± 0.1	17.1 ± 0.6	16.3 ± 1.0	28.6 ± 0.3	63.6 ± 0.2	0.7 ± 0.1

[a] %AFDW = Percent ash-free dry weight.
[b] WSC = water-soluble carbohydrates.
[c] ADF = acid detergent fiber.
[d] NDF = neutral detergent fiber.

Table 3. Macronutrient and total silica (expressed on a dry weight-basis) in Kentucky bluegrass (KYB), common bermudagrass (BERM), tall fescue (TTF), zoysiagrass (ZOY), creeping bentgrass (BENT), buffalograss (BUFF), fine fescue (FF), centipedegrass (CENT), and St. Augustinegrass (ST. AUG). Data are presented as mean ± 1 SE.

Turfgrass	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Sodium (%)	Silicon (mg/kg)
KYB	3.61 ± 0.07	0.31 ± 0.02	2.33 ± 0.06	0.43 ± 0.03	0.19 ± 0.02	0.04 ± 1.20	11,199 ± 394
BERM	1.76 ± 0.06	0.24 ± 0.01	1.13 ± 0.03	0.47 ± 0.09	0.14 ± 0.01	0.08 ± 0.01	12,085 ± 900
TTF	2.05 ± 0.09	0.42 ± 0.01	2.52 ± 0.04	0.22 ± 0.09	0.35 ± 0.01	0.01 ± 0.01	20,388 ± 529
ZOY	1.78 ± 0.07	0.31 ± 0.02	1.54 ± 0.03	0.18 ± 0.02	0.14 ± 0.01	0.01 ± 0.01	14,270 ± 322
BENT	5.29 ± 0.01	0.61 ± 0.01	3.28 ± 0.01	0.67 ± 0.02	0.24 ± 0.01	0.04 ± 0.01	4,826 ± 97
BUFF	2.18 ± 0.06	0.28 ± 0.01	0.92 ± 0.01	0.23 ± 0.05	0.12 ± 0.01	0.01 ± 0.01	22,510 ± 573
FF	3.08 ± 0.04	0.38 ± 0.01	2.55 ± 0.05	0.37 ± 0.01	0.19 ± 0.01	0.01 ± 0.01	8,877 ± 199
CENT	2.06 ± 0.06	0.34 ± 0.01	2.24 ± 0.02	0.28 ± 0.02	0.25 ± 0.01	0.01 ± 0.01	14,032 ± 360
ST. AUG	2.32 ± 0.02	0.46 ± 0.01	2.55 ± 0.02	0.15 ± 0.03	0.25 ± 0.01	0.43 ± 0.04	11,349 ± 753

closely related to creeping bentgrass. In addition to foraging, time in each plot might be spent loafing or in other non-feeding behaviors (Belant et al. 1997). Although geese also spent time in the zoysiagrass plots, they showed little preference for this turfgrass when foraging.

Overall, the rate of Canada goose foraging upon the various turfgrasses was consistent during the experiments, with 2 interesting exceptions. During experiment 3, the creeping bentgrass sod exhibited a visible reduction in turfgrass quality (it appeared to be dying from an unknown disease) which reduced the quantity and likely the forage quality of available bentgrass in the plots. Although Canada goose foraging rates decreased as the experiment progressed, they continued to forage on this sod at a high rate in all 5 arenas. This suggests that the creeping bentgrass provided a favorable forage (compared to other turfgrasses) to the geese. Canada goose foraging on buffalograss increased during experiment 3 and then steadily decreased during experiment 4. As buffalograss is a warm-season grass, we suspect the responses in feeding rate by geese followed the forage value of buffalograss during its annual cycle.

The nutritional content of most turfgrass species and cv. are unknown, primarily because these grass species or specific turf-type cv. are not used as for forage in animal production agriculture (Ball et al. 1991). Geese, because of their high daily energy requirements and simple gastrointestinal tract with a limited ability to digest fiber (Buchsbaum et al. 1986, Sedinger et al. 1989, Sedinger 1997), need to ingest large quantities of forage with high concentrations of digestible nutrients to meet their nutritional needs (Ydenberg and Prins 1981, Durant et al. 2004). Therefore, grazing Anatidae (including various species of geese) apparently make foraging choices based on the nutritional content and chemical composition of plants (Owen 1975, Gauthier and Bedard 1991, McKay et al. 2001). Geese prefer to forage on plants that are high in water and protein content (Owen 1973, Owen et al. 1977, Sedinger and Raveling 1984, McKay et al. 2001). Digestible crude protein intake is an important component in the foraging decisions of geese (Sedinger 1997, Durant et al. 2004). Protein concentration within forage plants has been shown to influence forage selection in a variety of goose species, including barnacle geese (*Branta leucopsis*; Prins and Ydenberg 1985), dark-bellied brent geese (*B. bernicla bernicla*; McKay et al. 2001), white-fronted geese (*Anser albifrons albifrons*; Owen 1976), graylag geese (*A. anser*; Van Liere et al. 2009), and gosling Canada geese (Sedinger and Raveling 1984). In this study, adult Canada geese foraged most on and therefore seemed to select turfgrasses (i.e., Kentucky bluegrass, creeping bentgrass, and fine fescue) that exceeded 20% protein (or nitrogen) content.

In addition to protein levels, ADF might influence forage selection by geese. The turfgrasses fed upon most often by Canada geese in this study (i.e., Kentucky bluegrass and creeping bentgrass) had low levels of ADF whereas turfgrasses that were less fed upon (i.e., centipedegrass and zoysiagrass) contained high levels of ADF. Gauthier and Hughes (1995) found that high fiber content appeared to reduce greater snow goose (*Chen caerulescens atlantica*) foraging on willow (*Salix* spp.) leaves. Also, Prop et al. (2005) found that ADF had a negative effect on the digestibility of organic matter by barnacle geese.

With the exception of calcium, our findings suggest macronutrient (e.g., mineral) content of turfgrasses does not appear to affect foraging choice by geese. Similarly, Mathers and Montgomery (1997) found forage choice in free-ranging pale-bellied brent geese (*B. bernicla hrota*) was related to forage quality (e.g., low fiber content) rather than mineral content of consumed forage plants. Prins and Ydenberg (1985) found protein levels, but not minerals, influenced diet choice in wintering barnacle geese. However, lesser snow geese (*C. caerulescens caerulescens*) selected plants based on the nutrient content in order to obtain necessary minerals (nitrogen, calcium and phosphorous) to promote growth while on their breeding grounds (Gadallah and Jefferies 1995). Consequently, mineral content of plants might influence goose forage selection during certain periods of the year when energetic demands for those minerals are high (e.g., egg production).

Secondary plant defense compounds, such as alkaloids and tannins, cause geese to limit intake of or avoid feeding on certain plants (Buchsbaum et al. 1984, Conover 1991, Gauthier and Hughes 1995). The tall fescue endophyte (*Neotyphodium coenophialum*) is a naturally occurring fungus that forms a symbiotic relationship with the grass (Ball et al. 1991). Secondary plant defense compounds (e.g., alkaloids) produced by endophyte-infected tall fescue act as a feeding deterrent (e.g., taste aversion) by causing post-ingestion distress in animals that consume the plant (Aldrich et al. 1993, Schmidt and Osborn 1993, Bacon and Hill 1997).

Many tall fescue cv. have high levels of tall fescue endophyte infection (Mohr et al. 2002). In this study, we used a turfgrass sod grown from a mix of endophyte-free and high-endophyte tall fescue cv. We suspect that the foraging on tall fescue that occurred (primarily in experiment 1) was a result either of the geese selectively grazing the endophyte-free tall fescue plants within the plots or geese were ingesting the high-endophyte tall fescue at levels low enough to avoid the negative effects of alkaloid consumption. Washburn et al. (2007) found captive Canada geese avoided foraging on high-endophyte tall fescue turfgrass sod when the percent of tall fescue within the sward exceeded 90%. Also, Conover and Messmer (1996) reported captive Canada geese preferred to graze on non-infected tall fescue cv. compared to endophyte-infected tall fescue cv., and that geese foraging on endophyte-infected tall fescue suffered negative effects (e.g., lost body mass).

In addition to nutrient levels and plant defense chemicals, physical characteristics of turfgrasses (e.g., leaf tensile strength, hairy leaves) might influence forage selection by Canada geese (Lieff et al. 1970, Williams and Forbes 1980, Conover 1991). Although we did not specifically examine physical characteristics of turfgrasses in our study, we believe future research efforts to further understand the influence of physical and/or nutritional characteristics upon forage selection patterns in Anatidae might consider evaluating physical characteristics of turfgrasses.

We acknowledge our study was conducted in a captive setting and that free-ranging Canada geese might exhibit different foraging preferences among turfgrasses that are available with a given landscape. We recommend field trials be conducted in various parts of the United States (and elsewhere) to determine which turfgrasses and turf-type cv. might be useful in different physiographic regions of North America.

MANAGEMENT IMPLICATIONS

The findings from our 3-year study of foraging preferences by Canada geese suggest selected commercially available turfgrasses (e.g., zoysiagrass, centipedegrass, and St. Augustinegrass) might be particularly useful in reseeding and vegetation renovation projects within areas where Canada geese are unwanted (e.g., parks, athletic fields, airports, and golf courses). Conversely, creeping bentgrass, Kentucky bluegrass, and fine fescues should be avoided when formulating seed mixtures for reseeding areas where human–goose conflicts might occur. We recommend managers and landscapers use caution when selecting common bermudagrass and buffalograss for reseeding projects, especially when other less preferred turfgrasses are present in the general area.

The avoidance or preference for certain turfgrasses by foraging geese might be due to the nutritional value, the physical characteristics of these turfgrasses, the presence of secondary plant defense compounds, or a combination of factors. Thus, an understanding of how the physical and nutritional characteristics of commercially available turfgrasses influence forage selection by geese could be useful for predicting the attractiveness of those plants to Canada geese and allow for the selection of grasses that might reduce human–goose conflicts in some situations.

Attractiveness to foraging wildlife (e.g., Canada geese) is one aspect of turfgrass selection that must be balanced with the aesthetic and recreational values of turfgrass areas for humans. In addition, managers and landscapers must consider the availability, ease of establishment, and maintenance ability of selected turfgrass species and cultivars when selecting turfgrasses for reseeding and revegetation projects.

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